From Misconceptions to Constructed Understanding
The Fourth International Seminar on Misconceptions Research (1997)

Article Title: Constructivistic teaching methods helping students to develop particle models in science

Author: Tveita, Johs

Abstract: We have used untraditional teaching methods as well as traditional ones in teaching particle models in science like the kinetic particle model of matter and the electron model for electric circuits to students from grade-6 to grade-10 . The methods called untraditional are drama (role play), concept mapping, writing about being particles (creative writing) and students "teaching" their parents about the models they have learned at school. Most research shows that these models are difficult to understand and to use. By using these untraditional methods alongside traditional ones more students were able to get a sound understanding of the particle models and able to explain physical phenomena by using these models.

Keywords:
General School Subject:
Specific School Subject:
Students:

Macintosh File Name: Tveita-ParticleModels
Release Date: 10-2-97 A, 10-22-97 B, 12-3-97 C

Editor: Abrams, Robert
Publisher: The Meaningful Learning Research Group
Publisher Location: Santa Cruz, CA
Volume Name: The Proceedings of the Fourth International Misconceptions Seminar - From Misconceptions to Constructed Understanding
Publication Year: 1997
Conference Date: June 13-15, 1997
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

work, consider supporting our ability to support you by purchasing a subscription to the collection or joining the Meaningful Learning Research Group.

Constructivistic teaching methods helping students to develop particle models in science.

Johs. Tveita
Nesna College, Norway
Completion Date: 8-24-97

ABSTRACT

We have used untraditional teaching methods as well as traditional ones in teaching particle models in science like the kinetic particle model of matter and the electron model for electric circuits to students from grade-6 to grade-10 . The methods called untraditional are drama (role play), concept mapping, writing about being particles (creative writing) and students "teaching" their parents about the models they have learned at school. Most research shows that these models are difficult to understand and to use. By using these untraditional methods alongside traditional ones more students were able to get a sound understanding of the particle models and able to explain physical phenomena by using these models.

INTRODUCTION

For almost two decades studies have shown that students from secondary school to university hold incomplete or inaccurate understandings of many natural and scientific phenomena. Students develop their own explanations of phenomena which often contradict the scientific explanations. These nonscientific explanations have got many different names: misconceptions, preconceptions, everyday conceptions, students conceptions, general knowledge, common sense, alternative frameworks, children´s science, spontaneous reasoning, intuitive beliefs, nonscientific ideas etc. In the litterature «misconceptions» is, however, the most common name, even though most people working in this field don´t like it!(This conference name is: «From misconceptions to constructed understanding»!) In Scandinavia it is common to use **everyday conceptions** for these nonscientific explanations. For a database-review with some three thousand studies of everyday conceptions see (Duit & Pfundt, 1994).

These everyday conceptions often persist even after the students have been taught the scientific conceptions at school. Students also often get wrong ideas about new scientific concepts we try to communicate in the classroom, e.g. they mix the concepts of current and voltage. You still find the term misconception used in new papers, but it is more common to use this term only about wrong ideas that students tend to develop from science teaching (Duit & Treagust, 1995).

Why are the everyday conceptions so resistant toward teaching? Svein Sjoberg asks the question: «Maybe they describe reality quite well, give expected results, are socially accepted and correspond quite well with everyday language?» (Sjoberg, 1996). You will probably get in trouble when communicating with family and friends if you are using only scientific conceptions in everyday life! But on the other hand in school science and in scientific work we need scientific models and conceptions in order to get a deeper understanding of the world.

Our understanding of the world can be viewed as a cultural phenomenon, we have the life-world culture, and in school we try introduce the students to a culture of science(Aikenhead, 1996). Joan Solomon maintains that if bridging between these two cultures is encouraged, then it will certainly produce more durable learning (Solomon, 1984; Solomon, 1993)! On the other hand she and other researchers in the field find that students discussing their own everyday conceptions in small groups often reinforce these conceptions. The teacher is a very important participant or a scaffolding in helping students to recognise a new way of thinking about the world in terms of scientific concepts and theories (Wood, Bruner, & Ross, 1976).

THEORY, MODELS AND ANALOGIES

According to educational constructivist theory learners have to construe, actively, what they learn. This active construction is based on the already known! But some of this already known (everyday conceptions) conflicts with accepted scientific theory. To explain the phenomena of the physical world is one of the primary objectives of the natural sciences. In science we explain the world by introduce models and these models are often taken from the life-world and are often mechanical, e.g. the planet model of the atom and the water model for electric circuits. These models are often difficult for students to understand, because students are not familiar with them. The water model for electric circuit is unfamiliar to most students and therefore does not help them to understand the different phenomena with electric circuits.

Here I want to introduce teaching strategies and models I used in two studies to help students to get a sound understanding of 1) the kinetic particle model (Tveita, 1993a; Tveita, 1994) and 2) the electron model for simple circuits (Tveita, 1996a). Both these models can explain many phenomena, but several studies show that students don´t understand them.

The hypotesis is: *The scientific models are too abstract for the students, and that traditional teaching methods are not sufficient for students to construct useful models in their minds.*

In these two studies I introduce carefully worked out analog drama models in order to help the students to develop a useful thinking instrument to explain the phenomena. With help of these analog models as thinking instruments, we think that the students can more easily develop mental models of the phenomena(Duit & Glynn, 1995). We also introduced several teaching methods to force the students to think about the phenomena and the analog models e.g. the conceptual change approach (Posner, Strike, Hewson, & Gertzog, 1982).

INTRODUCING THE KINETIC PARTICLE MODEL TO MIDDLE SCHOOL STUDENTS

The essence of the kinetic particle model can be summarized as follows: *"Matter consists of tiny particles, called molecules, which are constantly in motion."*(Lee, Eichinger, Anderson, Berkheimer, & Blakeslee, 1993). In this study we used the term particle instead of the term molecule.

Many daily life phenomena that are seemingly unconnected can be explained by using the kinetic particle model, e. g.:

- solids expand when heated - because the particles vibrate and take up more room
- the smell of perfume - because some perfume particles escape from the bottle and travel quickly through the surrounding air particles
- food colouring spreads in water - because the particles of the two substances are in constant motion and will hit each other, and consequently the colour will be distributed

- spilt water on the floor disappears - because the water particles are in motion and escape from the water´s surface and mix with the air particles

Several topics in science depend on the kinetic particle model to get a meaningful understanding: Osmosis and diffusion, photosynthesis, the water cycle, ecological matter cycling, the Second Law of Thermodynamics, and so forth.

This scientific model is, however, rather abstract: *Gas particles are like hard billiard balls, they collide perfectly elastic and have no volume!*

Students everyday conceptions of matter

In the study the students first have to explain which model they have for a gas. The test is almost the same as the one used by Novic and Nussbaum (Novic and Nussbaum, 1981; Nussbaum, 1985). As in most studies, we found that before teaching very few students had ideas of a particle model of gas, *they thought of gas as a continuum*. Even after traditional teaching of the kinetic particle model few students have a sound idea of the particle model. See Anderson, 1990 for the results from several studies.

After having explained their model of a gas, the students did experiments with air using syringes. They discover that air can compress by squeezing the piston and that it can expand by itself, when they were not squeezing the piston. In this way, the students soon concluded that the continuum model of air most of them believed in could not be correct. In a class discussion following the experiment, the students concluded that air consists of particles with space between was easy to conclude with by the students. We ended the discussion by drawing particles as small spheres in a syringe.

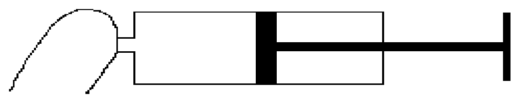
The drama analogy for the kinetic particle model

Gas

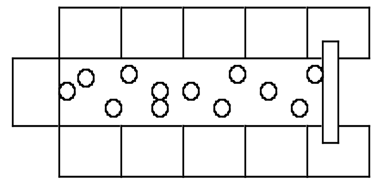
The idea that the particles are in motion we introduced by explaining the pressure against the piston in a locked syringe filled with air. We used a play where the students are actors and play particles:

1) The students who play particles have to move slowly in straight lines and with their arms along their body.
2) When colliding with the walls or with each other, they have to reflect like balls (elastic reflection)
3) One or two students move the “piston of the syringe” (the log).

Figure 1.
The left figure: Picture of a real syringe closed with a finger.



The right figure: Students playing particles in a closed "syringe".
The "syringe" is made up by desks and the "piston" is a log.



By playing particles between the desks ("walls of the syringe") and the log (the "piston" see Figure 1), the students experience how the pressure builds from colliding with the desks and the log.

To control the movement of the particles, we play music and the students have to follow the rhythm. We use mostly slow rock so that students do not hurt each other when colliding.

We introduced the connection between the motion of the particles and the temperature by doing an experiment with air expanding when being warmed up. The students dramatized this by playing particles. Here the teacher "changed the temperature" by singing a song or beat the rhythm and gradually increase the rhythm.

During the gas part of the unit the students were given two homework assignments:

- show and explain why air can be compressed in a syringe (Appendix B)
- show and explain how air expands when being heated in a bottle

<u>Fluid.</u>

Through class discussion the students agreed that fluids like water have to consist of particles; because water could become gas (vapour) and they had already agreed that gases consist of particles. By putting water in a syringe, the students realized that water could not be pressed together like air. They realised that the water particles had to be very near each other. We also dramatized water, but it was not so fun as gas and for solids.

We introduced peas in a baker as an analogy to water. By shaking the baker the student could see that the model had many properties of a fluid, e.g. horizontal surface, and filling up the baker from the bottom. By putting some green peas in the baker of yellow peas and shaking the baker, the students could see the green peas mixing with the yellow ones. The pea model thus explained that temperature (the shaking) causes the spread of colour in water!

The students did many simple experiments that they discussed and explained by applying basic kinetic particle model:

- putting some water on a desk and having the same amount of water in a baker near by, and see which disappears first.

- putting some food colour in warm and cold water and observe that colour spreads faster in warm water.
- dissolving a coloured salt in hot and cold water and observe that the salt dissolves and spreads faster in warm water.

The students got homework where they were to show to their parents/adults that sugar dissolves faster in hot water than in cold water. They were also to explain this by using the particle model.

Solid.

We ended the unit by looking at some properties of solid matter. The students, now used to the particle explanation, suggested that the particles in a solid stick together. After discussion in the class, they agreed about an analogy model like figure 2:

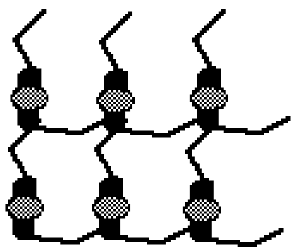


Figure 2. When dramatizing a solid the students hold each other on their shoulders, but they can still move a little by bending their elbows.

The students did some simple experiments that they discussed and could explain by the particle model, such as:

- melting ice by putting some ice cubes in a beaker early in a lesson.
- conduction of heat by putting a metal rod in a flame.
- tearing a thin metal wire into pieces
- expansion of solids by warming a metal wire

These phenomena with solids were easy and popular to dramatize and even easy for the students to explain using the drama analogy!

HELPING THE STUDENTS IN BUILDING THEIR OWN MENTAL PARTICLE MODEL

Making a hypothesis before doing experiments. The students discuss and explain the phenomena of the experiment by using the drama analogy.

We have picked out experiments that are easy to do and to explain by the drama analogy or the particle model. Most of the experiments are connected with the everyday life of the children, e.g. blowing up a balloon or dissolving sugar in cold and hot water.

Two or three children were working together as a group when doing the experiments. For each experiment, there was a worksheet telling the students what to do. Most often they had to make a *hypothesis* of what was going to happen and to explain why by writing on the worksheet. See Appendix A.

By making hypotheses we think that the students get more engaged in what is going to happen and why it is going to happen in an experiment.

In a questionnaire on the statement: “I like doing experiments” boys scored 4.35 and girls 4.07 on a Likert scale from 1(not agree) to 5 (agree) (See table I). We can conclude that the experiments we did and the ways to do them were a very popular activity (Tveita, 1993b).

Students formulate ideas

When teaching, formulating or explaining some difficult ideas in your own words, you often get a better understanding of these ideas yourself. In this unit we used several methods to get the students to formulate their ideas:

- Discussions in the classroom.
  After having finished an experiment, the teacher and the students discussed what had happened and why. The students were encouraged to explain the experiments using the particle model. The teacher monitored this discussion of the students´ explanations in class, so as not to reinforce their everyday conceptions (Solomon, 1995).
  Trying to explain was popular probably because dramatizing made this more personal and interesting.

- Summary by drawing concept maps.
  The students and the teacher summed up the ideas by drawing a concept map (Novak & Gowin, 1984) after about every fourth lesson (See Appendix E). When discussing the ideas, the teacher drew a concept map on the blackboard and the students drew the same map in their books. In this way, we removed misunderstandings during the discussion and no one made erroneous concept maps.
  Drawing the concept maps together in class was stimulating to the discussion of the ideas in the class. Most of the teachers reported that collaborative activities with construction of concept maps have help the students in meaningful learning. This has also been shown elsewhere (Okebukola & Jegede, 1988; Roth & Roychoudhury, 1993; Willerman & Mac Harg, 1991). Some teachers said that the concept map was a good way for themselves to get an overview of what they had taught!

- Writing about being particles.

The students were assigned to write small stories like: "My life being an air particle trapped in Kari`s balloon". See Appendix C. In Table I we see that this activity was the only activity that was more popular among girls than among boys with statistical significance of $p<.05$ on a two-tailed t-test.

By reading the stories the teacher could uncover misunderstandings of the kinetic particle model, e.g. some particles die when they get too cold. Such misunderstandings could then be discussed in class.

All of the nine teachers who were interviewed about this activity thought it was a good activity for teaching science.

- Homework to do and to explain experiments.

Some experiments that the students did at school they also had to show to their_parents and/or other adults at home. They had to explain the experiment by using the kinetic particle model! The adults were instructed to be skeptical to the explanation and to discuss the explanation with the student. The kinetic particle model was also unknown for most of the parents/adults, and in this way the students were teachers to their parents/adults! See Appendix B.

As we see from the table I, these two activities were on average the least popular of the activities among the students. From the high Standard Deviations, we see, however, that the students disagree a lot about this. On the other hand, we see from the table II that these activities were very much appreciated by the parents! The parents even think that they have learned something by the model! Maybe this is a way of getting scientific ideas better known in society?

Before doing a home experiment, many students asked the teacher many questions about the experiment and about explaining the experiment using the particle model. These assignments have obviously motivated some students to learn the model more thoroughly!

Doing homework and explaining experiments to parents/adults is a good idea, but we need further research to improve this activity. Some experiments the students did at home were very popular, but others were too dull. It is important to find experiments that are interesting both for the students and for their parents. We should probably prepare the students better to teach their parents, e.g. by drawing concept maps just before the students get their assignments.

The teaching strategies reported here are probably more powerful in combination than they are in isolation as also claimed by other researchers (Smith, Blakeslee, & Anderson, 1993).

TABLE I
Mean Scores and Standard Deviations of students who have answered the question on a Likert scale from 1 (not agree) to 5 (agree).

Questions	Boys (N=55) X_b	S.D	Girls (N=54) X_g	S.D.	Differences $(X_g - X_b)$
I liked this unit	3.56	1.12	3.63	.88	.07
I liked doing the experiments	4.35	.78	4.07	.89	-.28*
I liked playing particles	3.24	1.15	3.15	1.37	-.09
I liked doing experiments as homework	2.67	1.36	2.85	1.14	.18
I liked explaining the particle model to adults	2.51	1.23	2.61	1.14	.10
I liked writing about being particles	2.74	1.22	3.28	1.23	.54**
I liked drawing particles	3.35	1.27	3.48	1.04	.13
I liked answering the worksheets	3.11	1.31	3.43	1.04	.32
I think I understand the particle model	4.16	.79	4.30		

* $p < .05$ on one tailed t-test. ** $p < .05$ on two tailed t-test.

TABLE II
Mean Scores and Standard Deviations of parents (females and males) who have answered the question on a Likert scale from 1 (not agree) to 5 (agree).

Questions	Female (N=51)		Male (N=32)	
	X	S.D	X	S.D.
The home experiments did not take much of my time	4.36	0.94	4.47	0.95
To be shown and explained the home experiments were a fine experience	4.26	0.87	3.97	1.15
The home experiments were a good way to see what my child learned in science at school	4.51*	0.80	4.09*	1.20
I think I have learned something about the particle model from what the child explained	3.72	1.08	3.47	1.19

*p< .05 on one tailed t-test.

RESULTS FROM THE KINETIC PARTICLE STUDY

We used divided paper and pencil tests:

- In the first part the students were to explain some phenomena from life-world. We only used everyday language so as not to remind them on the particle model. The students have to answer the problems in written. See Appendix D.
- In the second part of the tests we reminded the students of the concepts of the particle model. The students had to explain some phenomena by writing or drawing. We also used some multiple choice questions in this part of the tests.

4 classes (58 students) in Grade-7-8 and 2 classes (29 students) in Grade-6-7 went through 15 lessons with the kinetic particle course and have answered the tests at least one month(Test1) and twelve months (Test12) after the unit was finished. In the everyday language test the students had to formulate their answers in writing.

We have divided the answers in two categories:

1) those using particles in their explanations

2) those using both particles and that the particles are moving in their explanations

TABLE III

The results from an everyday language test, Test1(25 students Grade-6, 59 students Grade-7) 1 month after teaching. Test12 is from an everyday language test for the same students 12 months after teaching.

	Using particles in the explanations	Using both particles and that the particles are moving
Test1 Grade-6 (1 month after teaching)	92 %	68 %
Test1 Grade-7 (1 month after teaching)	93 %	74 %
Test12 Grade-6(+1) (1 year after teaching)	93 %	48 %
Test12 Grade-7(+1) (1 year after teaching)	93 %	64 %

Over 90 % of all the students who were taught the particle models in Grade-6 and Grade-7 used the particle concept both 1 month and 1 year after teaching the model. Before teaching only about 3 % of the students in Grade-6 and about 30 % of the students in Grade-7 used a particle model when describing what air in a bottle «look like» when wearing magic glasses.

About 70 % of the students used «the particles are moving» when explaining phenomena in the life-world 1 month after teaching. 1 year after teaching only 48 % of Grade-6(+1) students and 64 % of Grade-7(+1) used «particles are moving» in explaining phenomena.

When the students, however, in a multiple choice test estimated these statements in the theoretic part of the tests 1 year afte teaching: «Particles are always moving» and «The higher temperature, the higher velocity of the particles» more than 90 % of the students gave correct answers! The results and discussion of the tests are found elsewere (Tveita, 1996b).

When comparing the results of the tests 1 month after teaching and 1 year after teaching we got about the same results. I think this implies that students who gave the correct answers after 1 month have developed their own useful mental particle model and therefore are able to give the correct answer 1 year later!

My conclusion is that at least 70 % of the students with 15 lessons of the particle model have developed a sound understanding of the model.

THE ELECTRON MODEL FOR SIMPLE CIRCUITS

Electricity has a strong impact on the daily life in the world today. Children develop their own conception for thinking about electricity. Those alternative conceptions are often taken from more familiar fields, especially mechanics (Maicle, 1981), and these concepts are often in conflict with the concepts of science.

In recent years many researchers have shown that students from secondary level up to university level have developed alternative conceptions about basic electricity(Anderson, 1989; Anderson, Bach, & Emanuelsson, 1992;

Dupin & Johsua, 1987; Shipstone, Rhoeneck, Jung, Kaerrqvist, Dupin, Johsua, et al., 1988):

The most common alternative conceptions about basic electricity are:

1) The concepts of current and voltage are confused.
2) Battery is the source of the current or the electrons.
3) Current is consumed by the bulbs or other forms of resistance.
4) Local or a sequential model of current flow: The current interacts with an electric component first when it passes the component, and this has no effect of the current for the whole circuit.
5) The battery is a constant current generator. Current supplied by the battery is considered to remain constant regardless of changes in the circuit.

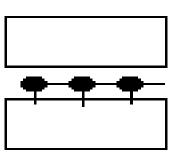
The most common model for helping students to understand electricity is the water analogy. But research has shown that the traditional water model is quite unfamiliar and therefore is not helping them to get a better understanding of electricity (Dupin & Johsua, 1989).

Dupin and Joshua proposed a «train analogy» inspired by Härtels bicycle chain for electric current (Haertel, 1982): A continuous train moves around a circuit. In a station, «people» push the cars with a constant force. Dupin and Joshua used the train analogy only as a thinking instrument and the students were not experimenting with real play cars.

THE DRAMA ANALOGY FOR ELECTRICITY

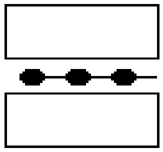
Using drama has been very useful for introducing analogy models in science (Gianello, 1988; Tveita, 1993a). Inspired by the train analogy, we introduce the drama model to represent simple circuits e.g. battery, wire and a bulb. In this drama model, the students are acting as electrons and batteries. The tables are placed to make the road (representing conductor, resistance or battery) on which the student electrons can move. The student electrons are instructed to do the following:

a) «Electrons» are standing with their arm stretched out to the shoulder of their neighbor.
b) When the «electrons» feel a push on their shoulder, they have to move in the direction of the push and move faster if the push is stronger.
c) If their stretched arm has no shoulder to push at, they have to stand still.



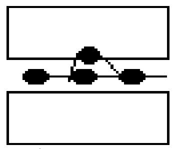
drama wire

In drama **wire** «electrons» can move with «no resistance».



drama resistance

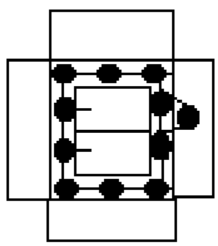
In drama **bulb** or **resistance** the «electrons» have to slide their free right hand on the table and thus resist their moving.



drama battery

In a drama **battery** we have a student sitting on one of the tables and pushing constantly on the shoulders of the student electrons.

A simple circuit consisting of a battery, a bulb and two wires can than be represented as follows:



A simple drama circuit

Summary of the drama model for electricity:

- the **current** is represented by how fast the student electrons are moving.
- because each of the student electrons is in touch with his neighbor on both sides. The student electrons are all moving at the same speed, and therefore the current of students is the same in every part of the drama circuit.
- the electromotive force or the **voltage** of the battery is represented by the push on the students shoulders when passing the battery
- local voltage is the push on the shoulders between each student.
- **resistance** is friction between the free hand of the student electrons and the resistance table

Hypothesis: *By working with the drama model of electricity the students will develop a better understanding of the concepts of current and voltage. More students will develop the correct scientific conseptions and avoid the most common everyday conceptions than with traditional teaching.*

I have made the following unit for teaching simple electric circuits:

1) We start by finding out which everyday conceptions the students have about electricity. This is done by administering a paper and pencil test before any teaching of electricity (see Appendix A).

2) The students get batteries, lamps, and circuits and are asked to do the experiments they want to in groups of 2. They are given worksheets describing experiments. Before doing the experiments they must form their own hypotheses (see Appendix F).
3) We then introduce the electron model. We use the analogous and more simple drama model to explain simple circuits. The students are acting as electrons and batteries. The tables are placed to make the road (representing wire, resistance and battery) on which the student electrons can move.
   First, we explain the components of the model. Then the students dramatize a simple circuit, consisting of wires, a bulb and a battery. All the student electrons have to go at least one whole turn of the circuit and thus have acted an «electron» when being in a resistance (bulb), in a wire and in a battery. When dramatizing in the class, we stop several times and discuss the analogy to the electric circuit. E.g.: The battery student normally gets exhausted (empty of energy) and we have to «change battery» by putting in a fresh battery student to push the student electrons around the circuit. Here we discuss the use of energy of the battery, and that the «electron chain» helps to transmit the energy to the bulb. We also discuss how the bicycle chain transmit energy from the pedals to the rear wheel of the bicycle.
4) The students get worksheets with diagrams and problems of some similar experiments as they have done under item 2. This time they have to explain the results in groups of two students by drawing a dramamodel for each experiment! (See Appendix H)
5) When the electricity unit is finished, the students have to answer a paper and pencil test.
6) At 3 months and 1 year after having finished the program of electricity the students answer a paper and pencil tests of some of the same questions as the start test, but also some new questions (See Appendix I). We think that if the students answer the problem correctly 1 year after teaching, they have a model to lead them, and not just remember the right answer.

The students also have to write short stories, e.q. about being a «real» electron in a circuit.

The author has worked out this model by teaching electricity to teacher trainees for several years. In the spring 1995, the author started a pilot study with the unit in a Grade-6 class, in autumn 1995 the author tried the unit in a Grade-10 class. Both these classes were taught electricity for only 8 lessons. In the Norwegian school, simple electric circuits are normally taught in Grade-8 During the winter/spring of 1996 five teachers in Grade-7 and Grade-8 tryed out a slightly revised version of the drama unit in their classes. The students have answered 2 tests one at least 3 monthes after finishing the unit and one at least 1 year after finishing the unit. The tests are of the multiple choice type. See Appendix F and I.

RESULTS FROM THE ELECTRICITY STUDY

This project is still under evaluation and will be reported elswere. We have, however, some preliminary results:

Conservation of current .
For our Grade-7 and Grade-8 students (13-15 yers old):
Before teaching 10%-15% of the students gave correct answer.
3 months after teaching about 80 % gave correct answer.
1 year after teaching about 60 % of correct answers.
The results from 15-17 years old students in five European countries have a mean of 43 % (from 35 % to 55 %) on this concept(Shipstone, et al., 1988).

Concepts of current and voltage
To the statement:
«There can exist voltage without a current» about 65 % gave correct answers one year after teaching.
Maicle has used the same claim for Grade-8 students in Germany (Maicle, 1981) got only 30 % correct answers.
On the task 4, Appendix I, our students gave about 30 % correct answers on all the claims one year after teaching. For the two different groups of Grade-8 German students Maicle got only 2 % an 8 % correct answers.
Several researchers claim that students with traditional teaching confuse the concepts of voltage and current(Anderson, et al., 1992). Dupin and Johsua claim that voltage was fundamentally misunderstood by the subjects; it remained isolated and nonoperational (Dupin & Johsua, 1987).

The teachers who have finished the drama unit with Grade-7 and Grade-8 students agreed that this model, compared to the water model, help the students to distinguish better between the concept of current and voltage.

Regarding the misconception «a battery is a constant current generator», see Appendix F, 60 % of students in Grade-7 and Grade-8 still sticked to it 3 months after teaching. This misconception is thus very resistant to learning also with the drama unit. From an extensive investigation on French students, Dupin and Joshua reported that 60-70 % of the students hold this misconception even when studying at the university! (Dupin & Johsua, 1987).

We have taught the drama analogy for electricity to students in Grade-6, Grad-7, Grade-8 and Grade-10, as well as to teacher trainees. The preliminary results show that the drama model help the students to get a better understanding of the concepts of current and voltage, than by traditional methods. More students have developed the correct scientific conceptions than by traditional teaching.

CONCLUSION

In this article I have introduced drama as a way of helping students to develop scientific concepts and to get rid of everyday conceptions. Using drama to help students to construct meaning in science and other subjects has also been stressed by researchers from the drama field (see Renk, 1993; Allern, 1993). Drama is a powerful way of knowing something from the inside; knowing about being a particle in a gas or being an electron in a circuit. Lewis and Davies say: «Essentially drama is personalising knowledge» (Lewis & Davies, 1988).

But drama is no hocus-pocus solution to everything. There should be a very close analogy between the science model and the drama analogy. Otherwise the students will develop new misconceptions. It is also important to discuss with the students that the model is not the real thing, but a way for us to think about the phenomenon. The students and the teacher should also discuss new misconceptions that the students may develop in connection with dramatizing, e.g. the electrons are living creatures.

By way of drama, we get the students to think, and I think it is easier to get the students motivated to use the other constructivistic strategies we have discussed here: concept maps, drawing particles, using macroscopic models, writing, discussing and teaching parents or other adults.

REFERENCE LIST

Aikenhead, G. (1996). Border Crossings into the Subculture of Science. Studies in Science Education, 27, 1-52.

Allern, T. (1993). The Drama Paradox and Teacher-in-role. In International Conferance at Lancaster University: The Work and Influence of Dorothy Heathcote, Lancaster:

Anderson, B. (1989). Elkretsar fran grundskola till universitet. En internationell oversikt (Elevperspektiv No. 18). Goeteborg Universitet.

Anderson, B. (1990). Pupils´ Conception of Matter and its Transformations (age 12-16). Studies in Science Education(18), 53-85.

Anderson, B., Bach, F., & Emanuelsson, J. (1992). Analogitaenkande och laerande. Med vattenkrets-elkrets som exempel. (NA-SPEKTRUM No. 2). Goeteborgs universitet.

Duit, R., & Glynn, S. (1995). Mental modelling. In G. Welford, J. Osborne, & P. Scott (Eds.), Science Education Research in Europe. Current Issues and Themes, . Leeds: Falmer Press.

Duit, R., & Treagust, F. (1995). Students´ Conceptions and Constructivist Teaching Approaches. in Fraser & Walberg (Eds.), Improving Science Education.

Duit, R., & Pfundt, H. (1994). Students Alternative Frameworks and Science Education. Kiel, Germany: IPN.

Dupin, J. J., & Johsua, S. (1987). Conception of French pupils concerning circuits: Structure and evolution. Journal of Research in Science Teaching, 24(9), 791-806.

Dupin, J. J., & Johsua, S. (1989). Analogies and "Modeling Analogies" in Teaching: Some Exemples in Basic Electricity. Science Education, 73(2), 207-224.

Gianello, L. (Ed.). (1988). Getting into gear: Gender inclusive teaching strategies in Science developed by the McClintock Collective. Canberra: Curriculum Development Centre.

Haertel, H. (1982). The Electric Circuit as a System: A New Approach. Eur. J. Sci. Educ., 4(No1), 45-55.

Lee, O., Eichinger, D. C., Anderson, C. W., Berkheimer, G. D., & Blakeslee, T. D. (1993). Changing Middle School Students´ Conceptions of Matter and Molecules. Journal of Research in Science Teaching, 30(3), 249-270.

Lewis, S., & Davies, A. (1988). Gender Equity in Mathematics 6 Science. Woden: Commonwealt of Australia.

Maicle, U. (1981). Representation of knowledge in basic electricity and its use for problem solving. In W. Jung, H. Pfund, & R. C. v. (Eds.), Problems concerning students´ representation of physics and chemistry knowledge, (pp. 194-213). Ludwigsburg: Pädagogishe Hochschule.

Novak, J. D., & Gowin, D. B. (1984). Learning how to learn. New York: Cambridge University Press.

Okebukola, P. A., & Jegede, O. J. (1988). Cognitive preference and learning mode as determinants of meaningful learning through concept mapping. Science Education, 72, 489-500.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. Science Education, 66(2), 211-227.

Renk, H. (1993). The art of drama and the new paradigme of constructivism. Geelong:

Roth, W., & Roychoudhury, A. (1993). The Concept Map as a Tool for Collaborative Construction of Knowledge: A Microanalysis of High School Physics Students. Journal of Research in Science Teaching, 30(5), 249-270.

Shipstone, D. M., Rhoeneck, C. v., Jung, W., Kaerrqvist, C., Dupin, J.-J., Johsua, S., & Licht, P. (1988). A study of students´ understanding of electricity in five European countries. International Journal of Science Education, 10(3), 303-316.

Sjoeberg, S. (1996). Scientific literacy and school science. Arguments and second thoughts. In ILS (Ed.), Technology and Citizenship, University of Oslo.

Smith, E. L., Blakeslee, T. D., & Anderson, C. W. (1993). Teaching Strategies Associated with Conceptual Change Learning in Science. Journal of Research in Science Teaching, 30(2), 111-126.

Solomon, J. (1984). Messy, contradictory and obstinately persistent: a study of children´s out of school ideas about energy. School Science Review, 65(231), 225-229.

Solomon, J. (1993). Constructivism and Quality in Science Education. In A. C. Paulsen (Ed.), Naturfagenes Pedagogik, 1 (pp. 17-29). Gilleleje: Nordisk Forskersymposium.

Solomon, J. (1995). Higher level understanding of the nature of science. School Science Review, 76(276), 15-22.

Tveita, J. (1993a). Helping Middle School Students to learn the Kinetic Particle Model. In J. D. Novak (Ed.), Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, . Ithaca: Cornell University.

Tveita, J. (1993b). Nye arbeidsmetoder i naturfagundervisningea brukt for aa formidle "Den kinetiske partikkelmodellen for stoffa" til grunnskoleelever. In A. C. Paulsen (Ed.), Naturfagenes Paedagogik – mellem udviklingsarbejder og teoridannelse, 2 (pp. 68-78). Gilleleje:

Tveita, J. (1994). Elevaktive undervisningsmetoder i naturfag brukt til å formidle den kinetiske partikkelmodellen for stoffa. Nesna: Høgskolen i Nesna.

Tveita, J. (1996a). The Drama Model of Electricity. In K. Calhoun (Ed.), 8th International Organization of Science and Technology Education Symposium, . Edmonton:

Tveita, J. (1996b). Er elevane i grunnskolen modne for aa laera den kinetiske partikkelmodellen? In O. Eskilsson & G. Helldén (Eds.), Naturvetenskapen i skolan inför 2000-talet, (pp. 524-532). Kristianstad: Det femte nordiska forskarsymposiet.

Willerman, M., & Mac Harg, R. A. (1991). The concept Map as an Advance Organizer. Journal of Research in Science Teaching, 28(8), 705-711.

Wood, D., Bruner, J., & Ross, G. (1976). The Role of Tutoring in Problem Solving. Journal of Child Psychology, 17.

Appendix A.
Student worksheet.
Spreading of a dye in hot and cold water.
Go to the hot faucet and get hot water and to the cold faucet and get cold water in the two beakers:

Cold water Hot water

The teacher is going to put a few drops of red dye into each beaker.
What do you think will happen with the dye in the two beakers?

....
Why do you think this will happen?

....

....

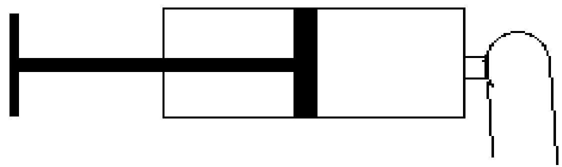
The teacher will put the drops into your beaker when you have answered the questions above.
Study carefully what is happening in the two beakers. Write down what is happening:

....

....
In which of the beakers does the dye scatter fastest?

....

Appendix B Student´s worksheet.
Homework: Air in a syringe.



Show the syringe to the adult(s) and what happens when you compress the air and then let the piston go!
Let also the adult(s) try this!

You have to explain to the adult(s) the kinetic particle model of air.

Draw particles in the picture of the syringe. Explain that the particles move and how they move!

Explain to the adult how this model can explain why we can compress the air in the syringe!

Explain also why the air resists being compressed and why we feel the pressure from the piston!

Tell also the adult(s) about experiments, demonstrations and about how we played particles in the class!

Appendix C.

Student´s worksheet.

Story writing: The changes of my life.

You are one of the ice particles in the experiment. Write a story about how it is to be an ice particle that first melts into a water particle and eventually evaporates to a steam particle.

Try to use some of these words: keep hold of, vibrate, moving around, get free, small velocity, high velocity, collide, particles, reflect.

Appendix D

Some of the questions from the test using everyday language.

These questions were answered at least 1 month and 12 months after finishing the kinetic particle unit.

Question 1.

A spoonful of sugar is added to a glass half filled with water. After a while the sugar has dissolved in the water.

Write a paragraph to explain what happens when sugar dissolves in water:

Question 3.

Write a paragraph to explain the similarities and the differences between warm water and cold water:

Question 4.

A clear plastic cup is half filled with water. The cup is set on a table where it will not be moved. After the water is still, a few drops of food coloring are carefully added to it. After a period of time it is observed that the water is uniformly colored blue.

Write a paragraph to explain how the food coloring mixes in the water:

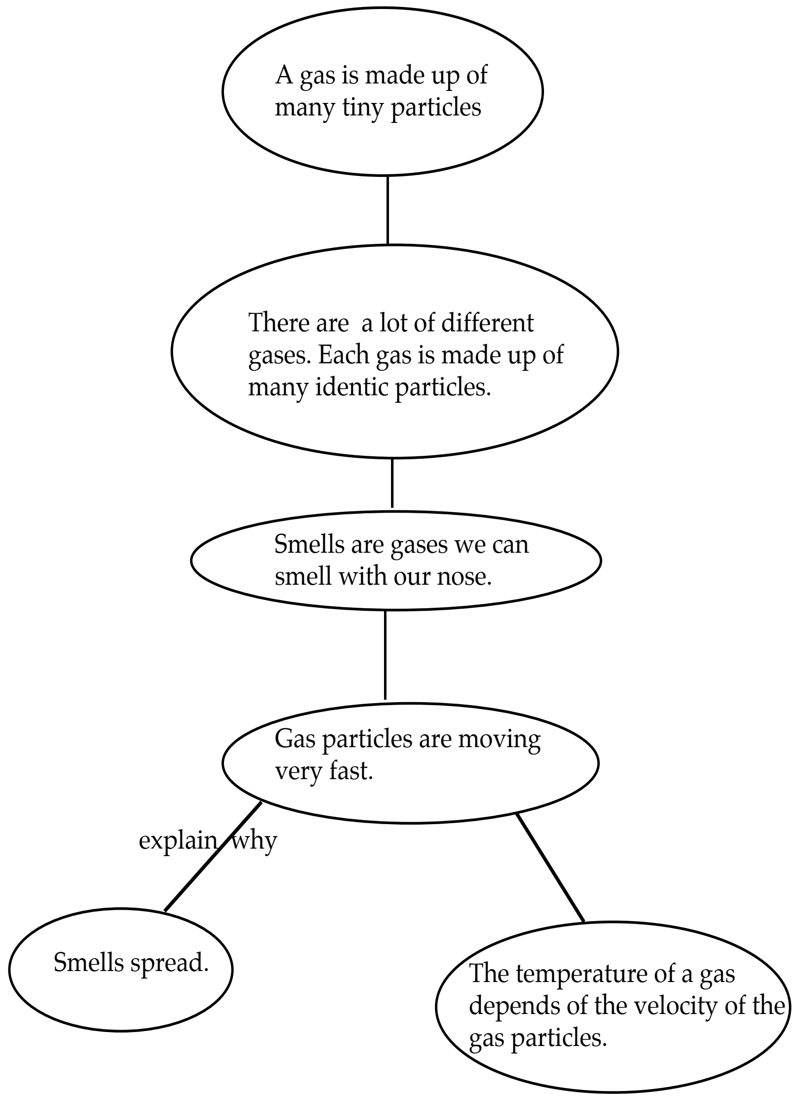
Question 8.

Water exists in three forms: gas (water vapor), liquid, and solid (ice).

Write a paragraph or more to explain the similarities and the differences among the three forms of water:

Appendix E.

Concept Map after the fourth lesson.



Appendix F. Examples of tasks from the paper and pencil test

Task 3

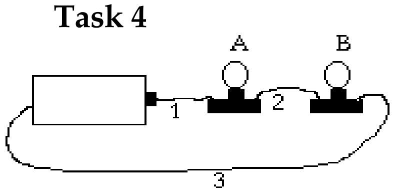
The bulbs drawn on the figures are identical.

a) What is happening with the light of bulb A when we put a new bulb in the circuit? ☐ Bulb A lights as before. ☐ Bulb A lights weaker then before. ☐ Bulb A does not light.

Compare the current in wire 1 before and after we have put in bulb B. ☐ The current in wire 1 is the same as before we put in bulb B.

☐ The current in wire 1 is less than before we put in bulb B.

Task 4



The bulbs A and B are identical. The bulbs A and B are identical and are coupled to the battery as shown on the diagram. How is the light from bulb A compared with bulb B?

☐ The light from bulb A is stronger than from bulb B.

☐ The light from bulb B is stronger than from bulb A.

☐ The light from bulb B is the same as the light from bulb A.

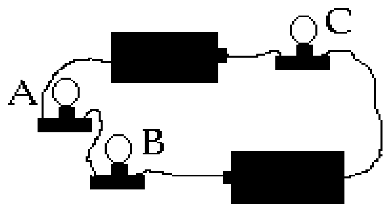
What about the current in the wires? ☐ There is more current in wire 1, less in wire 2 and the least in wire 3.

☐ There is more current in wire 3, less in wire 2 and the least in wire 1.

☐ The current is the same in all three wires.

Appendix G. Example of task on the worksheets.

Task 5



The bulbs and the batteries on the figure are identical. How do the bulbs light when coupled like the figure?
Decide (guess!) if the claims are true (T) or false(F), before doing the experiment!

	Guess T or F	Exper. T or F
a) A lights stronger than the two other bulbs	______	______
b) B lights stronger than the two other bulbs	______	______
c) C lights stronger than the two other bulbs	______	______
d) All the bulbs lights alike	______	______
e) A lights. B and C do not light.	______	______
f) B lights. A and C do not light.	______	______
g) C lights. B and A do not light.	______	______
h) None of the bulbs light	______	______

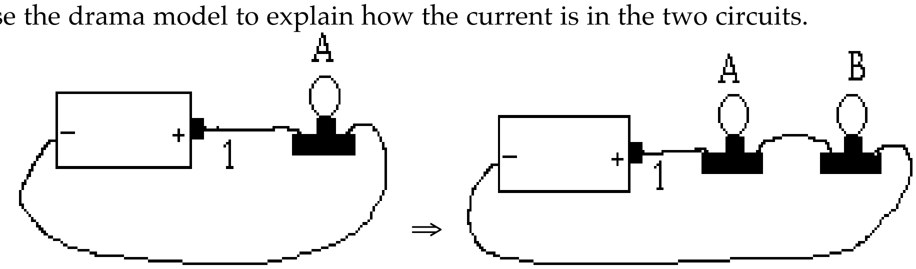
Do the experiment and find the right answer!

Appendix H. Example of task to explain with the drama model.

Task 2

Many students have the opinion that the current in wire 1 is the same in both the circuits. Is this correct?

Use the drama model to explain how the current is in the two circuits.



Task 3

Make drama models for the circuits:

Figure 1

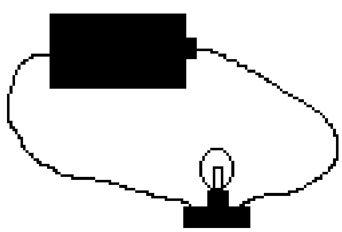
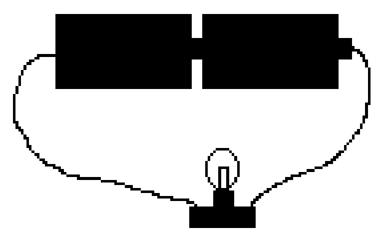


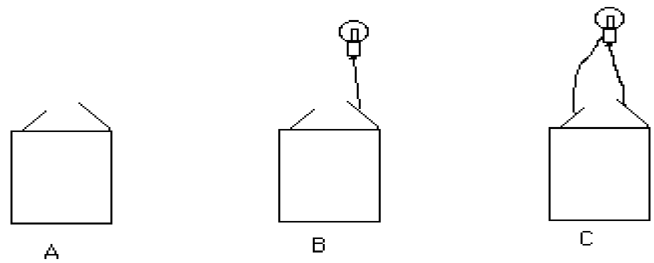
Figure 2



Explain why the bulb lights stronger in the circuit of figure 2 than in the circuit of figure 1.

Appendix I. Example of task from the final test.

Task 4



Which of the following claims are true (T) or false(F). Write T for true and F for false!

	T or F
a) There is electric current in A	______
b) There is electric current in B	______
c) There is electric current in C	______
d) There is voltage in A	______
e) There is voltage in B	______
f) There is voltage in C	______